NEOTROPICAL BIOLOGY AND CONSERVATION

Neotropical Biology and Conservation
16(1): 45–58 (2021)
doi: 10.3897/neotropical.16.e50156

RESEARCH ARTICLE

Arinosaster patriciae (Porifera, Demospongiae): new genus and species and the second record of a cave freshwater sponge from Brazil

Cecilia Volkmer-Ribeiro[1], Maria da Conceição Tavares-Frigo[1], Alexandre Cunha Ribeiro[2], Maria Elina Bichuette[3]

1 *Research Group of Spongology, Museu de Ciências Naturais, Fundação Zoobotânica do Rio Grande do Sul, Rua Doutor Salvador França, 1427, 90.690-000, Jardim Botânico, Porto Alegre, RS, Brazil*
2 *Universidade Federal de Mato Grosso, Departamento de Biologia e Zoologia, Instituto de Biociências. Avenida Fernando Corrêa da Costa n° 2367, Boa Esperança, 78060-900 Cuiabá, MT, Brazil*
3 *Research Group of Subterranean Fauna, Departamento de Ecologia e Biologia Evolutiva, Universidade Federal de São Carlos, Rodovia Washington Luís km 235, Caixa Postal 676, 13565-905, São Carlos, SP, Brazil*

Corresponding author: Maria Elina Bichuette (lina.cave@gmail.com)

Academic editor: A.M. Leal-Zanchet | Received 15 January 2020 | Accepted 30 December 2020 | Published 19 January 2021

Citation: Volkmer-Ribeiro C, Tavares-Frigo MC, Ribeiro AC, Bichuette ME (2021) *Arinosaster patriciae* (Porifera, Demospongiae): new genus and species and the second record of a cave freshwater sponge from Brazil. Neotropical Biology and Conservation 16(1): 45–57. https://doi.org/10.3897/neotropical.16.e50156

Abstract

Arinosaster patriciae gen. nov. et sp. nov. is the second continental sponge registered for a subterranean environment (cave habitat) in Brazil and the Neotropical Region. The sponges were recorded and collected in a 5m depth technical dive in a sinkhole of Rio Claro, tributary of Rio Arinos, Tapajós system, Amazon Basin (-13.8170386, -56.6914225) at the locality of Sumidouro do Rio Claro, Municipality of Diamantino, state of Mato Grosso, central western Brazil. The cave is placed in sandstone rocks of the Parecis Group (Upper Cretaceous). "In situ" photographs of colonies, of living specimens, SEM illustrations of dissociated spicules as well as of the skeletal structure, are presented. The occurrence of euaster microscleres of the type spherasters are for the first time reported for continental sponges but, also new, is the occurrence of spongin fibers, composing with fibers of silicious spicules in the skeletal arrangement. The absence of gemmules in the studied material and the fact that new specimens remain undetected call for the proposition of a new monospecific genus to be retained as *Incertae Sedis* until new and gemmuliferous colonies are found.

Copyright *Cecilia Volkmer-Ribeiro et al*. This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

PENSOFT

Keywords
Amazon Basin, caves, continental sponges

Introduction

Class Demospongiae Sollas, 1885 includes approximately 4,750 species in 10 orders. Their geographic distribution in the marine environment is from the intertidal to the abyssal zone; some species inhabit freshwater. Members of the Demospongiae can range in size from a few millimeters to over 2 meters in their largest dimension. They can form thin encrustations, lumps, finger-like growths, or urn shapes. (Sollas 1885; WoRMS 2020). The class Demospongiae now has three subclasses, Verongimorpha, Keratosa and Heteroscleromorpha, and each of these has a strongly altered set of orders.

We propose herein a new species and genus of Demospongiae sponge from a sandstone sinkhole of Rio Claro, tributary of Rio Arinos, Tapajós system, Amazon Basin, state of Mato Grosso, central western Brazil. The material has no gemmules, a fact not at all unknown in permanently submerged freshwater sponges. Because of this, we proposed herein a new genus, with an uncertain position in the class Demospongiae until future surveys in the river or the Amazon biome may produce gemmuliferous materials. This report is the first register of sponges in the Rio Arinos basin, southwestern limits of the Amazon biome in Brazil and the second for subterranean environment in Neotropical Region.

The only register of a cave freshwater sponge for the Neotropical Region was, until now, *Racekiela cavernicola* Volkmer-Ribeiro, Bichuettte & Machado, 2010, for the north region of Chapada Diamantina, state of Bahia, northeastern Brazil. *Racekiela cavernicola* encrusts rocky substrates under the shallow, clear waters of Jacaré River, inside Lapa dos Brejões, a limestone cave (Volkmer-Ribeiro et al. 2010), a different lithology and microhabitat of this new report from central western Brazil.

Material and methods

Study area

Sumidouro do Rio Claro is a sinkhole located in the drainage of Rio Claro, Rio Arinos basin, Tapajós system (-13.8170386, -56.6914225), municipality of Diamantino, state of Mato Grosso, Brazil (Figs 1, 2). The cave is located at an altitude of 225 m, inserted in the sandstones of the Utiariti Formation, which belongs to the Parecis Group (Upper Cretaceous), containing conglomerates, sandstones, and siliciclastic rocks (Barros et al. 1982; Lacerda-Filho et al. 2004). The sampled area falls into the limits of the Amazon Biome.

The Rio Claro is a typical clear water lotic system with intercalation of rapids and pools. In the sandstone cave, geological faults provide structural controls on the drain-

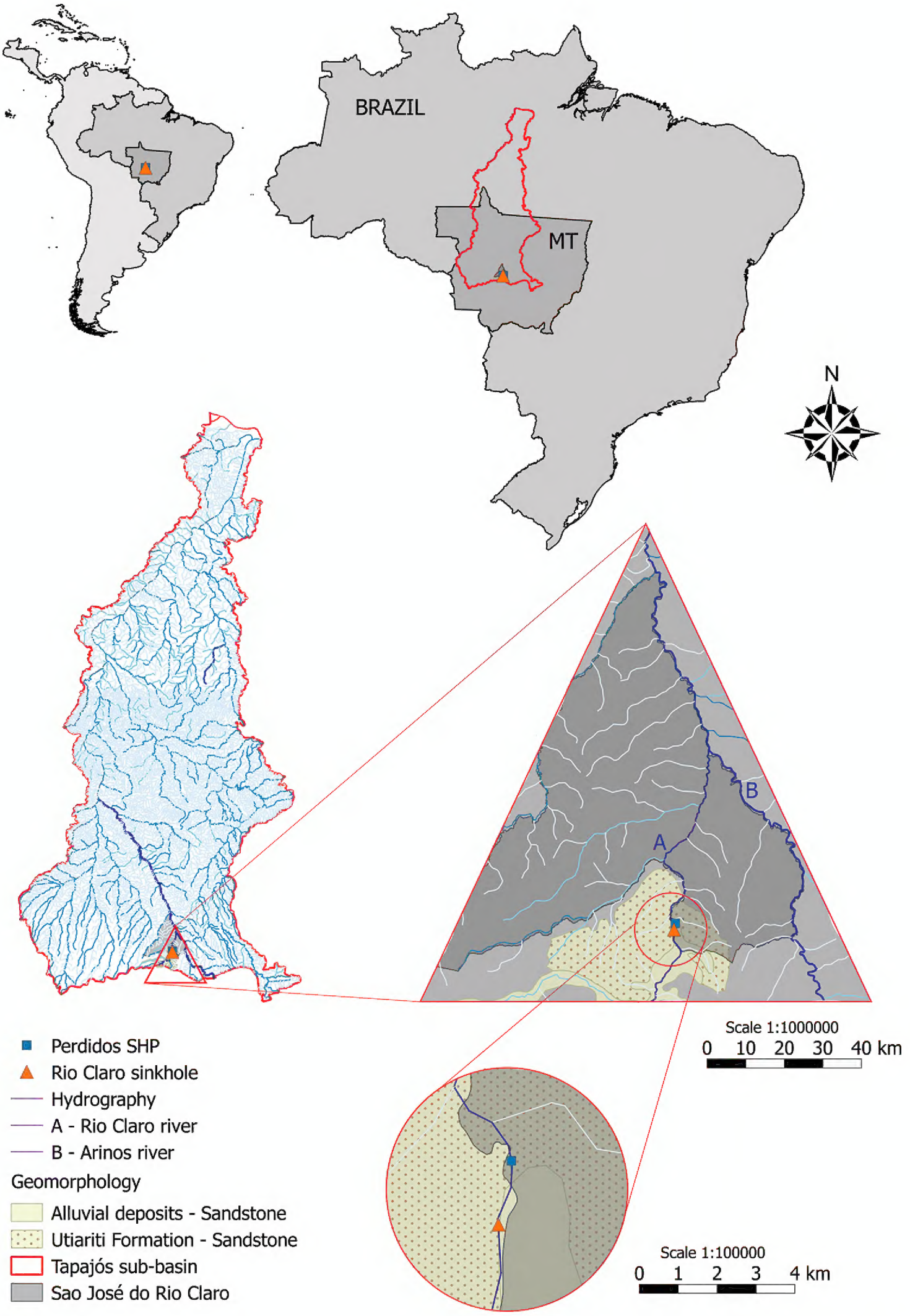

Figure 1. *Arinosaster patriciae* gen. nov. et sp. nov. Map of type-locality, Sumidouro do Rio Claro cave, River Arinos basin, state of Mato Grosso, Brazil.

age, and erosive processes associated with this fault system formed the cave, which has a conduit form. Rio Claro stream is subducted by the fault systems (Fig. 2A, B) and becomes completely subterranean in an extension of about 300 m, then resurges to the surface (Fig. 2C, D). The region has a tropical subhumid climate of the Aw type (Köppen-Geiger classification) with a dry winter (May to September) and a wet summer (October to April); the annual precipitation is 1,750 mm and the average temperature of 24 °C (Nimer 1979). Cerrado and riparian vegetation are the main type of domains; however the region has a high deforestation level due to large agriculture farms. The sponge colonies were encrusted in crevices of the sandstone rocky walls of a sinkhole, in moderate to strong water current, always in concavities of the rock vertical walls (Figure 3 A–C), where, however, fine sediments were deposited.

Methods

The specimens were photographed *in situ* and hand-picked upon scuba diving (Fig. 2C), fixed in alcohol 70 °GL in the field and subsequently sent to and preserved dry in the Porifera Collection of Museu de Ciências Naturais (MCN-POR) of Fundação Zoobotânica do Rio Grande do Sul, Porto Alegre, Brazil. In the laboratory, dry sponge fragments were subjected to Nitric Acid digestion of the soft tissues for light microscope and SEM studies of the cleaned spicules (Volkmer-Ribeiro and Turcq 1996). Dry sponge fragments were also placed on SEM stubs for observation of the skeleton structure. SEM work was performed with a FEI, Inspect F50, upon gold coating of the materials, at the Central Laboratory for Microscopy and Microanalysis, Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, Brazil. Descriptive terminology closely follows Boury-Esnault and Rützler (1997), Ehrlich and Wisokowski (2018). The map was produced using QuantumGis Essen software (2.14) with shapefiles of South America and Brazil.

Taxonomy

Class Demospongiae

Arinosasaster gen. nov.

Type species. *Arinosasaster patriciae* sp. nov.

Etymology. The genus name is formed by a combination of the river Arinos name with the word euaster, for some of the sponge remarkable microscleres. This is the first register of sponges for the Rio Arinos basin.

Diagnosis. Sponges with a combination of features: spongin fibers plus fibers of silicious spicules. Microscleres in three categories: spined micro oxeas, spherasters and spheres, and rare spiny spirasters, megascleres smooth oxea and shorter and robust anfistrongyla.

Description. Continental sponges forming thin whitish crusts with peripheral, tubular projections topped by a single larger oscular opening (Fig. 3A–D). Con-

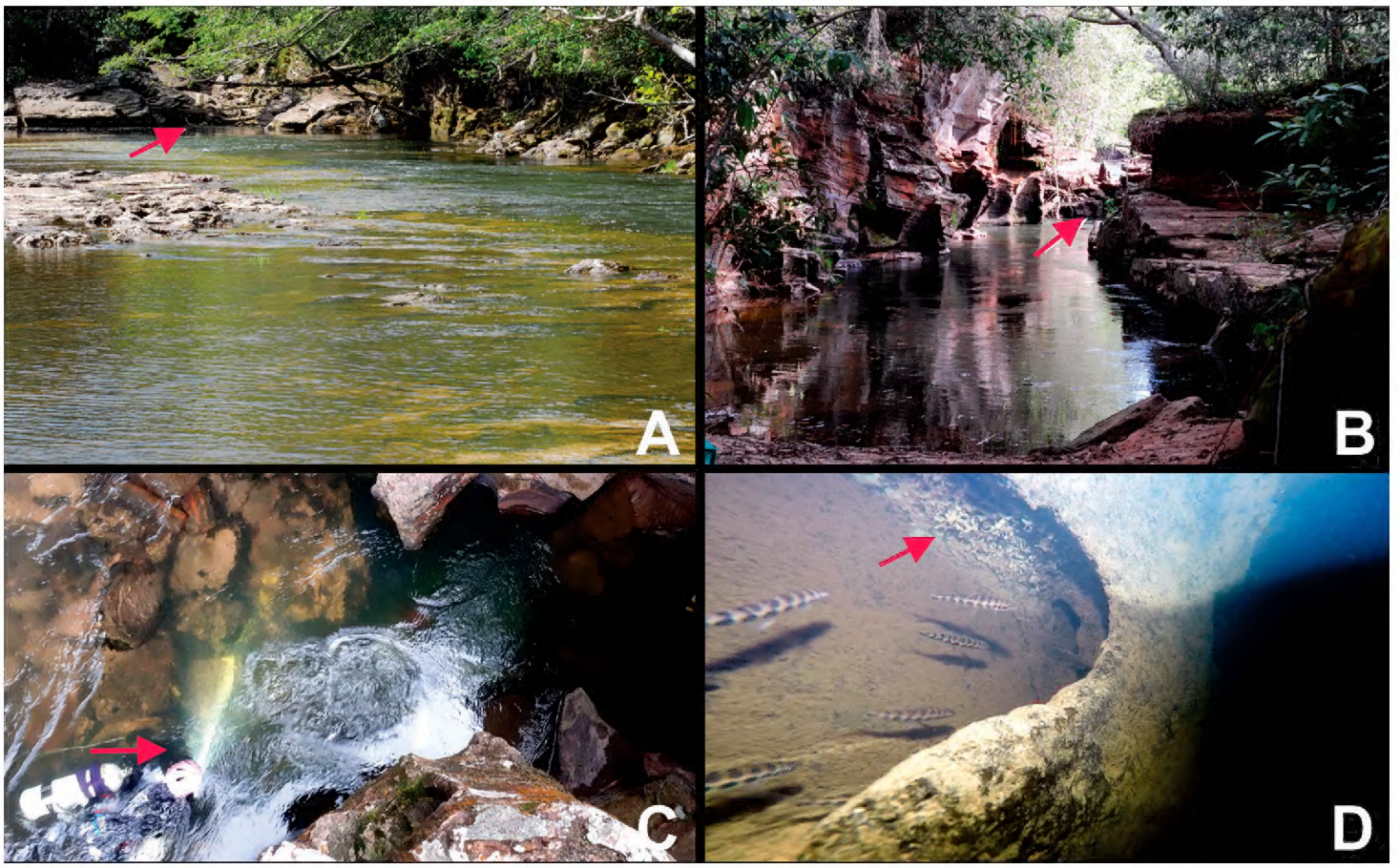

Figure 2. *Arinosaster patriciae* gen. nov. et sp. nov. **A** Rio Claro stream, close to the sinkhole; **B** Rio Claro stream at the resurgence from the sinkhole **C** Rio Claro at the entrance of the underwater cave showing the moment scuba divers are getting into the sinkhole **D** Colonies of *Arinosaster patriciae* gen. nov. et sp. nov. encrusted in crevices of the sinkhole rocky walls. Fish seen in D pertain to the species *Leporinus octomaculatus* Britski & Garavello, 1993. Photos **A–C** by Alexandre Cunha Ribeiro. Photo **D** by Patricia Arrais Rodrigues da Silva.

sistency fleshy-lime, elastic, surface hispid. Skeletal framework axial, with lateral fibers composing circular cameras. Megascleres in two categories. The first of long, smooth, abruptly pointed oxea compose the main skeletal framework; the second of shorter, smooth anfistrongyla, form small esparse peripheral fibers. Microscleres into three categories. Spined abundant oxea microscleres are followed by euasters of the type spherasters and spheres in more than one size category and yet rare spiny spirasters. Spongin fibers abundant and with irregular arrangements in the sponge body. Pinacoderm a thick spongin layer.

Distribution. Restricted to cave habitat (subterranean waters) in Sumidouro do Rio Claro, tributary to Rio Arinos, state of Mato Grosso, Brazil, Amazon Basin. Rio Arinos is a tributary to the headwaters of the Rio Tapajós. The genus is proposed as monotypic and is potentially troglobitic, but further studies are necessary to confirm the cave status.

***Arinosaster patriciae* sp. nov.**
Figs 3–8

Type-material. Holotype, MCN-POR 9131, at 5 m depth in a sinkhole at Rio Claro, tributary of Rio Arinos (-13.8170386, -56.6914225), municipality of Diamantino,

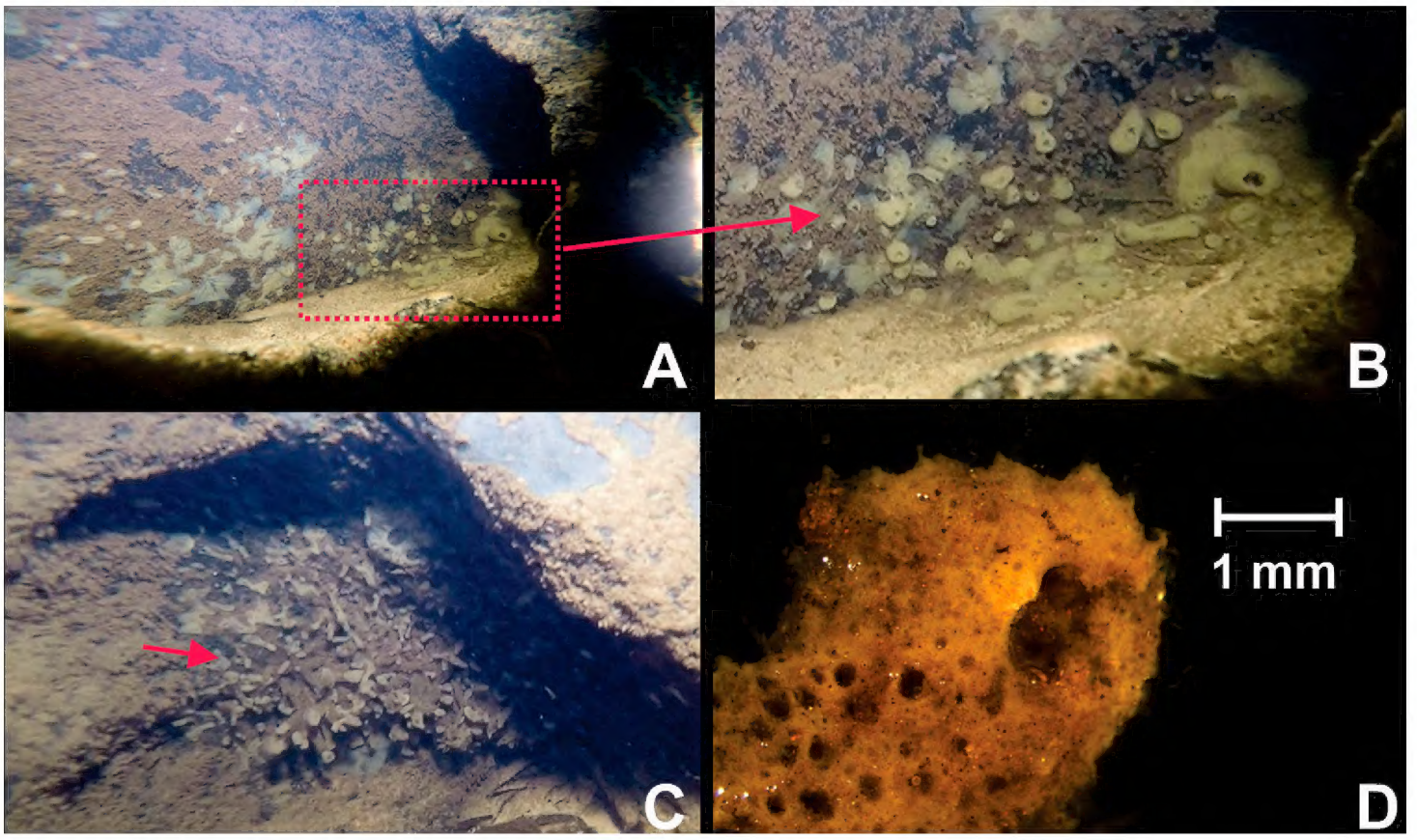

Figure 3. *Arinosaster patriciae* gen. nov. et sp. nov. **A–C** Details of the sponge colonies encrusting the sinkhole rock wall crevices, from the whitish initial borders to the grayish tubular projections surmounting the fine deposited sediments **D** One tubular projection of *A. patriciae* photographed in alcohol. Photos **A–C** by Patricia Arrais Rodrigues da Silva. Photo **D** by Alexandre Cunha Ribeiro.

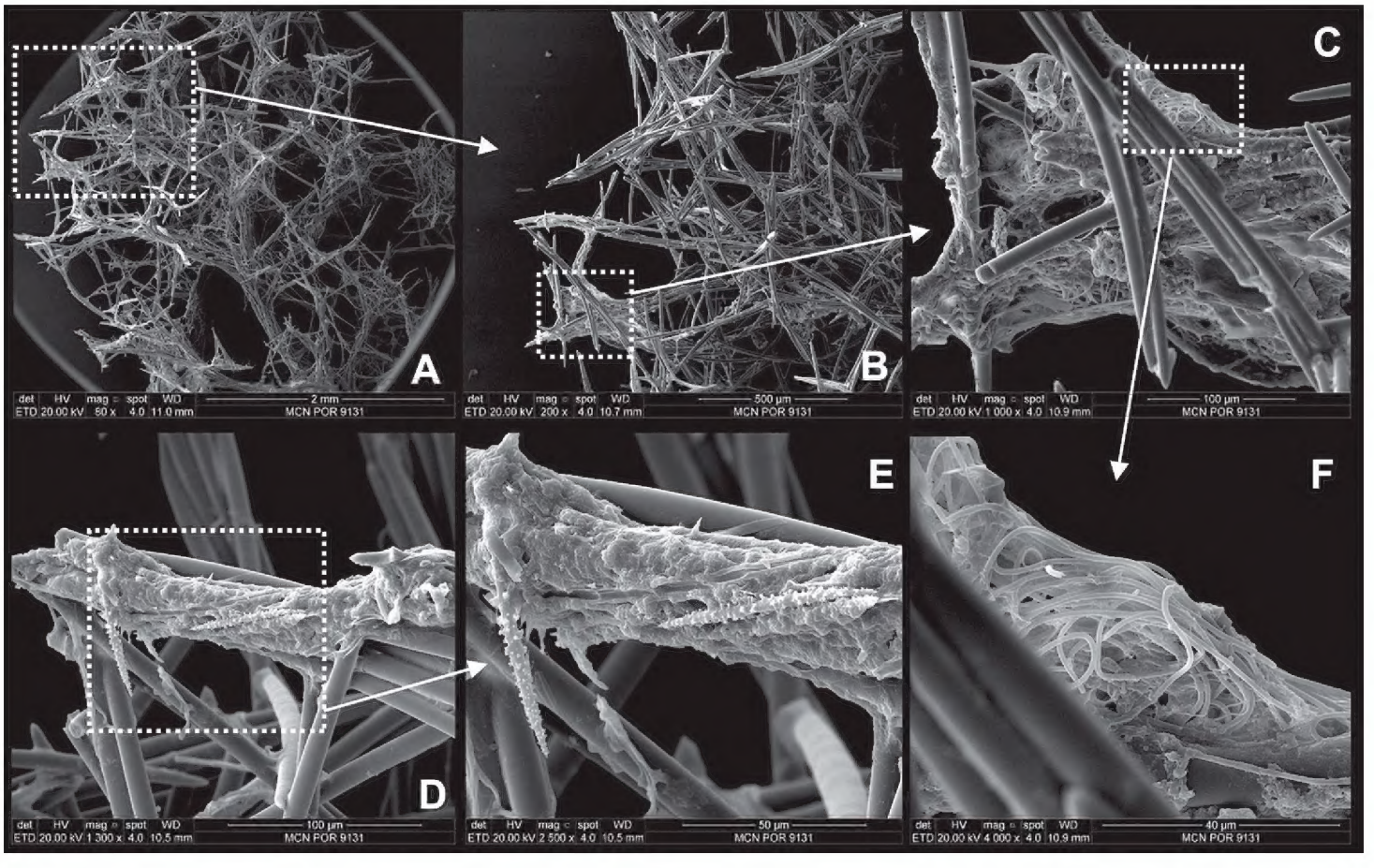

Figure 4. *Arinosaster patriciae* gen. nov. et sp. nov. SEM figures of the skeleton structure **A–F** Sections of the spicular network with its main spicule fibers, supporting an open meshwork of irregularly distributed lateral spicule fibers composing circular cameras. A network of thin sponging fibers is seen to mingle with that of the spicule fibers **F** Detail showing helicoidal concentrations of spongin fibers at the sponge wall.

state of Mato Grosso, Brazil. Luciano Heusner and Patrícia Arrais Rodrigues da Silva leg. 02/III/2017. Paratype MCN-POR 9132. Same data as for the holotype. Both are pieces of specimens fixed in alcohol soon after collecting and dried out subsequently in the laboratory in accordance with conditions recommended for preservation of freshwater sponge collections. The SEM mounted stubs with sponge fragments and dissociated spicules, as well as seven permanent slides of dissociated spicules for the holotype and two for the paratype, are also deposited.

Diagnosis. Same as for the genus.

Description. Sponges forming thin, spreading, fleshy-lime, grayish pink crusts in crevices of the rocky walls. Most of the crusts, buried in the fine sediment deposited in the crevices, produce irregular whitish, erect, conical, digitate or tubular projections (Fig. 3D) radially distributed at the crust periphery, each topped by a conspicuous oscular opening (Fig. 3A–D). Smaller oscula are, however, abundant in the walls of these projections (Fig. 3D). Consistency very fragile, the projections waving with the water movement. Surface hispid. Crusts around 5 cm large, the tubular projections about 1–2 cm high, surmounting the deposited gray sediment. Growing starts with whitish very thin crusts covered by a conspicuous translucent pinacoderm with large oscular opening or with asthrorizae (Fig. 3A–C). Skeletal framework axial, sending off lateral spicule fibers, among which an open meshwork of irregularly distributed secondary fibers, composes circular cameras (Fig. 4A–F). Spicular fibers almost deprived of sponging. However, a rich net of anastomosing spongin fibers with sparse beaded endings or growths (Figs 4, 5) supplements the spicular tracts from

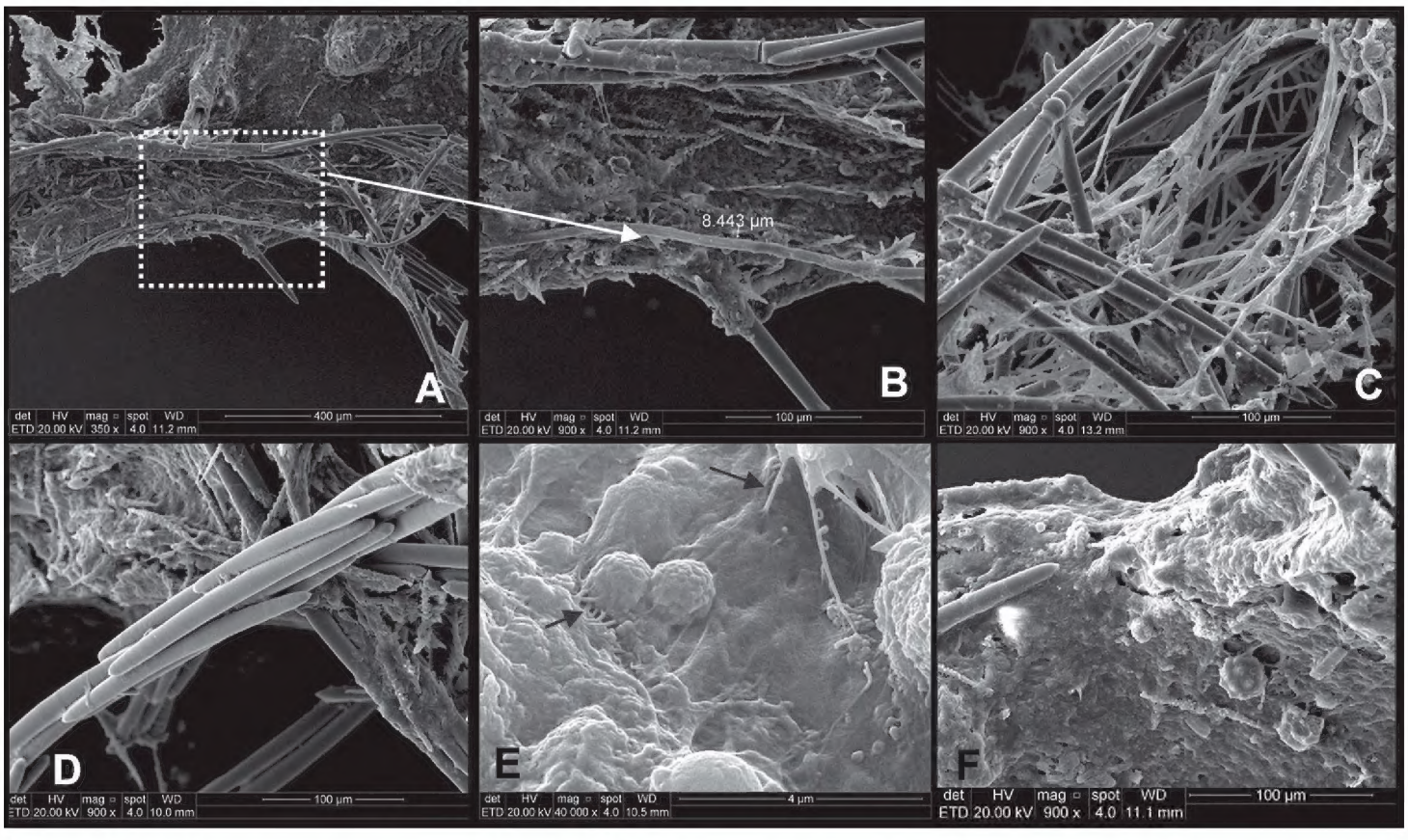

Figure 5. *Arinosaster patriciae* gen. nov. et sp. nov. SEM figures of the skeleton structure **B** Details of one sector in **A**, to show the sponge pinacoderm with a thick sponging fiber and spined micro oxea glued in **D** Fascicle of anfistrongylous megascleres protruding at the sponge periphery **E** Pinacoderm spongin with microasters and spongin fibers linked to the shaft of one spiny oxea microsclere **F** Ectodermal spongin with two spherasters and spiny oxea microscleres.

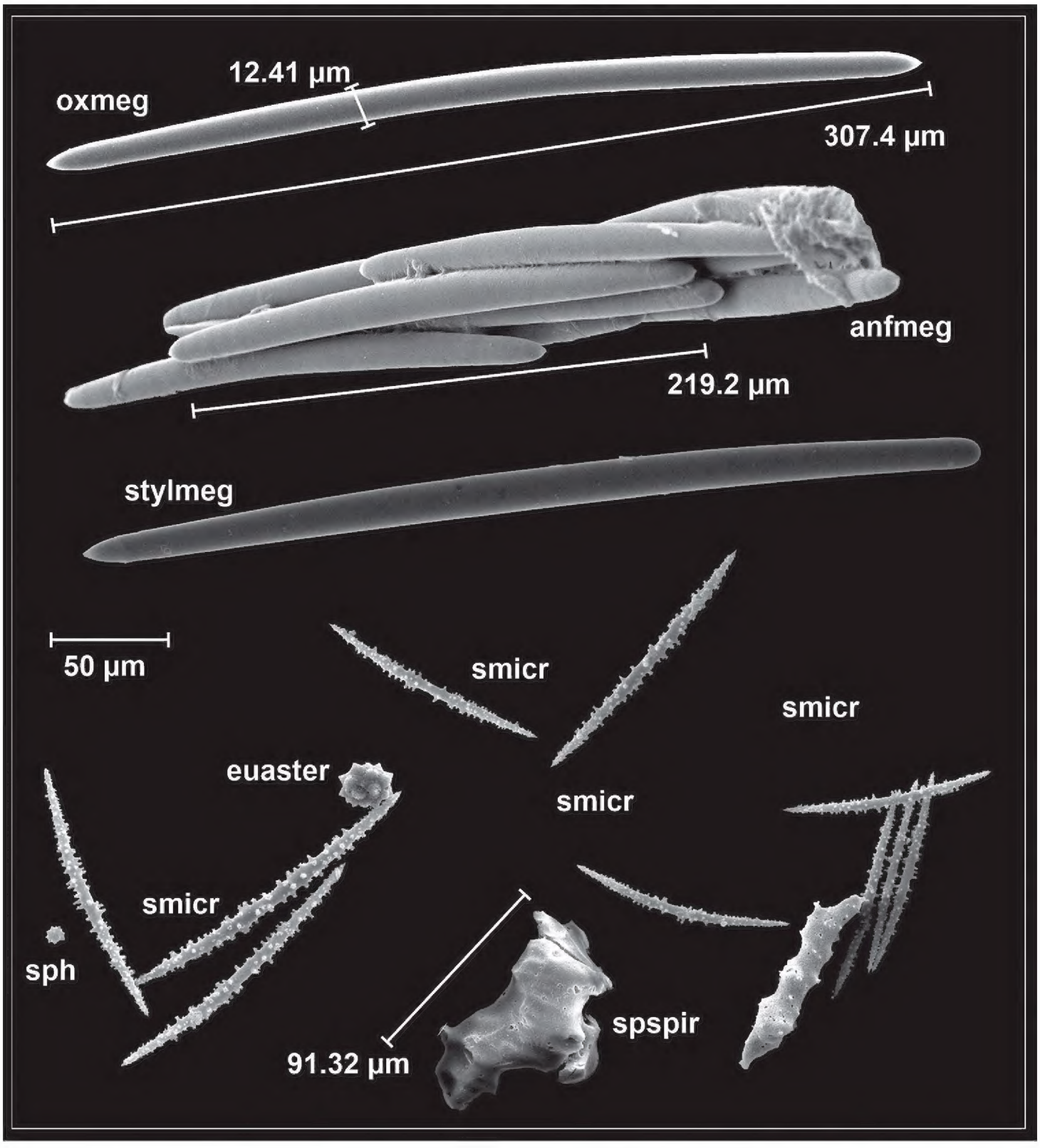

Figure 6. *Arinosaster patriciae* gen. nov. et sp. nov. Array of silicious spicules. Oxea megascleres:oxmeg; Anfistrongylous megascleres: anfmeg; Style megascleres: stylmeg; spined oxea microscleres: smicr; Sphere microscleres: sph; Spiraster spined microscleres: spspin; also one Euaster.

the base to the summit of the sponges. Pinacoderm a thick spongin layer stuttered with the several categories of microscleres (Fig. 5A, B, D, E, F).

Megascleres. Long, robust, smooth, abruptly pointed oxea, sometimes with middle enlargements, build up the main sponge skeleton (Fig. 5C). Groups of shorter, smooth, though robust anfistrongyla, are supported by the lateral main fibers, both protruding at the sponge surface (Fig. 5D). Rare smooth styles may be present. Spongin scanty to absent in the spicular fibers. Spicules figures and dimensions in Fig. 6 and in Table 1.

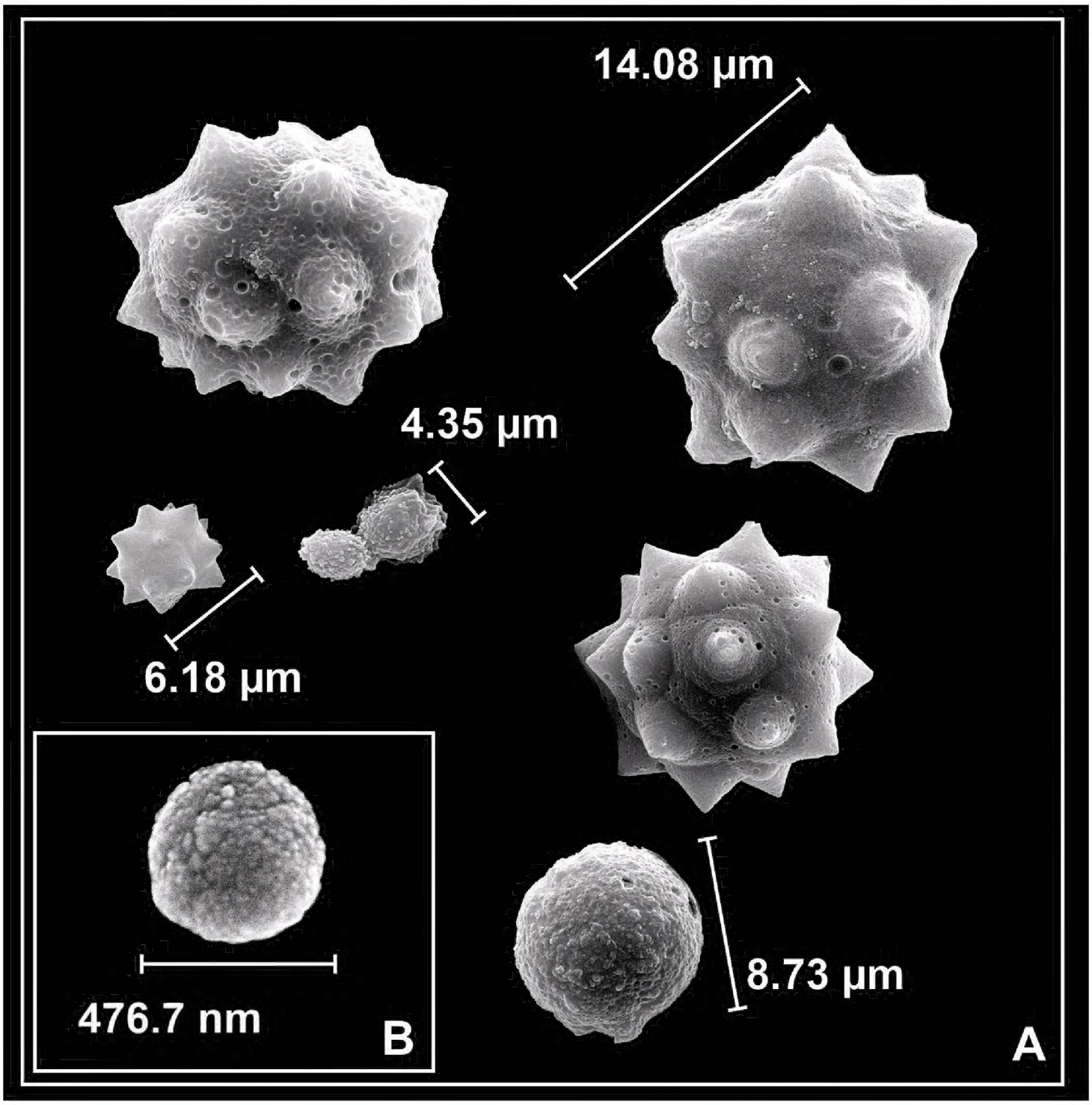

Figure 7. *Arinosaster patriciae* gen. nov. et sp. nov. The series of spherastter microscleres running from large spherasters to minor spheres.

Table 1. Spicule measurements of *Arinosaster patriciae* gen. nov. et sp. nov.

	Anfistrongyla					
Spicule categories	**Oxea megascleres**		**Megascleres**		**Oxea microscleres**	
	Length	**Width**	**Length**	**Width**	**Length**	**Width**
Minimum	338.18	10.36	381.10	19.61	98.00	4.70
Average	406.04	19.71	397.64	21.24	109.17	5.45
Maximum	446.59	25.16	414.40	22.57	122.11	7.35

Microscleres distributed in the pinacoderm into three categories: most abundant are the heavily spined oxea microscleres, followed by euasters, spherasters and spheres in more than one size category and yet rare smooth to spined spirasters. Oxea microscleres robust with harpoon-ended extremities and larger spines at the

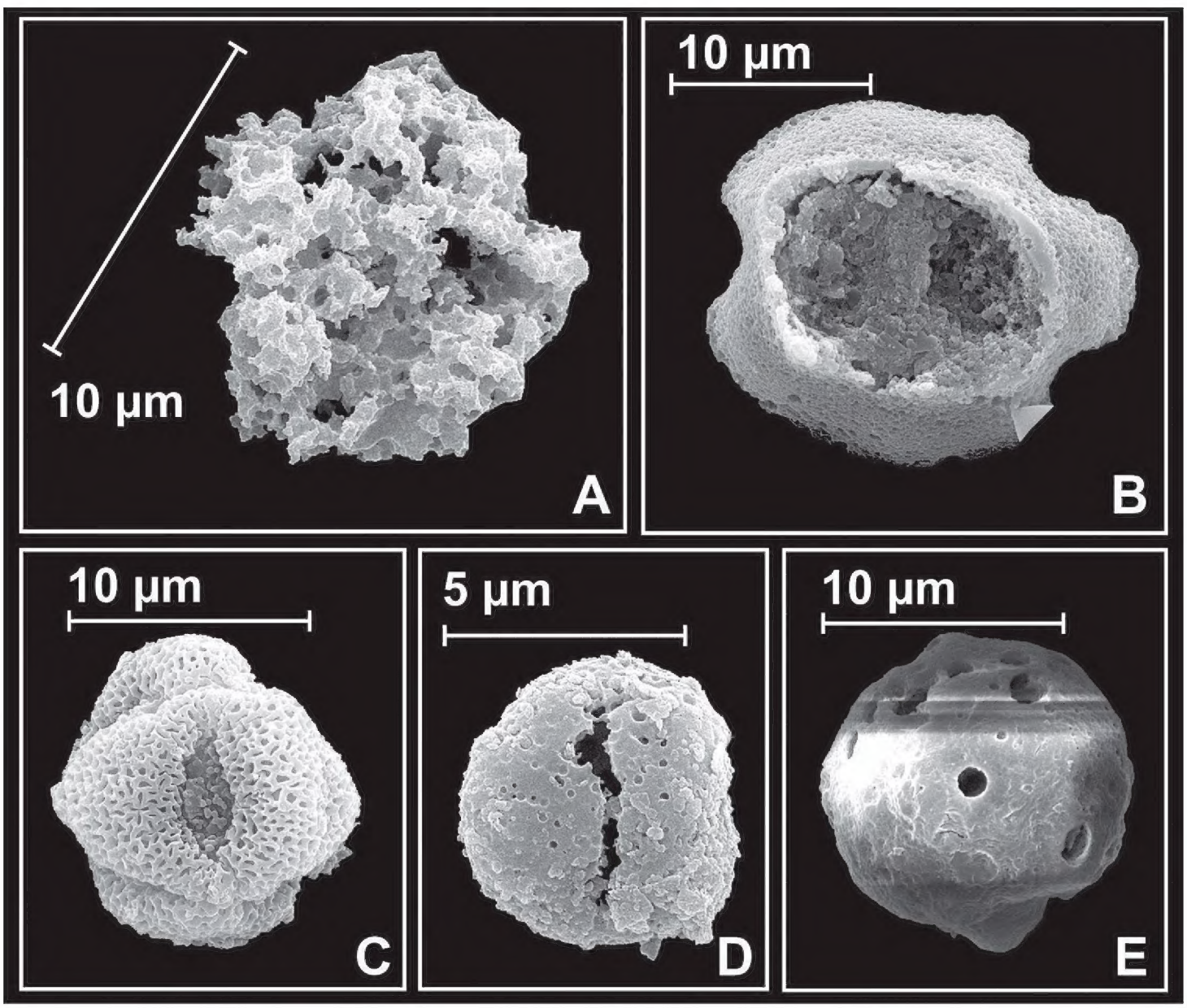

Figure 8. *Arinosaster patriciae* gen. nov. et sp. nov. Steps performed in the forming of spherasters.

central portion. (Figs 4D, E; 6). Several steps in the formation of the euasters and spheres are illustrated in Figs 7, 8. The rarity of spiraster microscleres was assumed from the fact that they were detected only in the preparations containing the dissociated spicules (Fig. 6). Spicules dimensions are also provided with scale bars in the SEM pictures.

Spongin fibers, with beaded endings or growths assume irregular open or closed patterns of distribution in the sponge body to the point of forming helicoidal concentrations close to the sponge surface. Larger ones 8.433 micrometers thick (Figs 4F, 5C)

Gemmules, and thus gemmoscleres, were not detected in the sampled materials. They may have not been sampled, may not be formed because of the permanent submersion or may not exist at all in this sponge.

Habitat. Sinkhole of Rio Claro, contributor to rio Arinos. The sponges encrusted crevices set at ca. 5 m depth in the vertical walls of the rock tube, though not devoid of fine sediment deposits but, at the same time, profiting from the oxygenated condition of its waters. The species may depend on good quality waters, since apparently the river is not polluted. Being found in subterranean waters possibly categorizes the new species as a troglobitic organism (species restricted to subterranean

environment) (Trajano and Bichuette 2006). However, more surveys are necessary to confirm this category.

Type locality. Sumidouro do Rio Claro, (-13.8170386, -56.6914225), Rio Claro, tributary of Arinos river, municipality of Diamantino, Mato Grosso state (MT), central western Brazil.

Etymology. The species name is dedicated in memoriam of the diver Patricia Arrais Rodrigues da Silva, who carried on observations, photographs and sampling procedures under dangerous diving conditions.

Discussion

The only register of a cave freshwater sponge for the Neotropical Region is that of *Racekiela cavernicola* Volkmer-Ribeiro, Bichuettte & Machado, 2010. *Racekiela cavernicola* encrusts rocky substrates under the shallow, clear waters of Jacaré River, inside Lapa dos Brejões, a limestone cave. *Racekiela cavernicola* presents abundant gemmules, thus making its generic and specific identification possible upon comparison with the genera of gemmuliferous continental sponges.

The second finding of a cave freshwater sponge from Brazil is now reported. However a completely different environment is seen to take place. The sponges were found and sampled with technical scuba diving at ca. 5 m depth inside a sinkhole of Rio Claro, tributary of Rio Arinos, Mato Grosso State, central western Brazil. The encrusting support for the sponges is provided by crevices in the permanently submerged vertical rock walls under strong water current. The SEM examinations of the sponge body revealed a microscopic structure not yet seen in other genus of continental sponges. These sponges are the first in freshwater environments to exhibit an astrose series of microscleres, besides spiny oxeamicrocleres and spirasters and yet spongin fibres, composing, with fibers of spicules, the skeletal arrangement.

The state of Mato Grosso has until now few registers of the continental sponges: *Oncosclera petricola* Bonetto & Ezcurra de Drago, 1967 of the family Potamolepidae Brien, 1969; *Corvospongilla seckty* Bonetto & Ezcurra de Drago, 1966; *Eunapius fragilis* (Leidy, 1851) and three species of genus *Trochospongilla* Vejdovsky, 1883 of the family Spongillidae Gray, 1867, i.e. *T. pennsylvanica* (Pots, 1882), *T. variabilis* Bonetto & Ezcurra de Drago, 1973 (Muricy et al. 2011).

The spicular set of *Arinosasaster patriciae* gen. nov. sp. nov. shows no parallel with those of the six upper referred species or with any of the world fauna of gemmulliferous or not gemmuliferous continental sponges. On the other hand sponging fibers have not been reported in continental sponges. Manconi and Pronzato (2002: 921) refer to freshwater sponges as with "spongin mostly sparse". The intriguing aspect of the surmounting presence of spongin fibers take to consideration of the fleshy consistency of a sponge, which has the capability of waving with the water current. It is not out of consensus to consider that the pendulum in their tubular projections is retained by a progressive spring system operated by the helicoidal ar-

rangement of the spongin fibers seen in the sponge wall, quite probably opposed to the direction of the water flow. The SEM studies of the dissociated spicules revealed what seem to be several steps of the biomineralisation process followed during the shaping of the spheraster type of microscleres.

Several continental sponges with remarkable morphological generic characteristics have not, up to now, presented gemmuliferous specimens. The taxonomic proposition in such cases has been that of *incertae sedis* genera, signaling the need of new survey efforts when new specimens may appear with those characteristics (Manconi and Pronzato 2002; Volkmer-Ribeiro et al. 2009; Muricy et al. 2011). Following these procedures the genus *Arinosaster* gen. nov. is proposed as *Incertae Sedis*.

Conclusions

Two continental sponges occur in subterranean environments in Brazil, *Racekiela cavernicola* in the Cerrado-Caatinga Biome (Bahia state, northeastern Brazil) and the one described herein, *Arinosaster patriciae*, gen. nov. sp. nov. in the Amazon Biome (Mato Grosso state).

The rarity of registers of continental sponges in cave habitats (presently restricted to one in the Paleartic Region and two in the Neotropical Region) must be related to the poor surveying efforts regarding this group and the difficulty in accessing some flooded caves.

The discovery and record of *Arinosaster patriciae* gen. nov. sp. nov. corroborates the extraordinary biodiversity richness of the Brazilian Amazonian realm.

Acknowledgements

The authors thank the staff of the Grupo Bom Futuro, Mato Grosso, which provided logistic and support for field expeditions and sponsored the collections. MEB thanks Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for productivity research fellowship (#310378/2017). Thanks also to Diego M. von Schimonsky for the map in Figure 1.

References

Barros AM, Silva RH, Cardoso ORFA, Freire FA, Souza-Jr JJ, Rivetti M, Luz DS, Palmeira RCB, Tassinari CCG (1982) Geologia. Geologia. Projeto RADAMBRASIL, Folha SD-21, Cuiabá. MME-SG, Rio de Janeiro, 25–192.

Boury-Esnault N, Rützler K (1997) Thesaurus of sponge morphology. Smithsonian Contributions to Zoology: 1–55. https://doi.org/10.5479/si.00810282.596

Ehrlich H, Wisokowski M (2018) Collagens of Poriferan origin. Marine Drugs 16(3): e79. https://doi.org/10.3390/md16030079

Lacerda Filho JV, Abreu Filho W, Valente CR, Oliveira CC, Albuquerque MC (2004) Geologia e Recursos Minerais do Estado de Mato Grosso. Escala 1:1.000.000. CPRM, Goiânia.

Manconi R, Pronzato R (2002) Sub-order Spongillina subord. nov: Freshwater sponges. In: Hooper JNA, van Soest RWM (Eds) Systema Porifera: A guide to the classification of sponges. Kluwer Academic/Plenum Publishers, New York, 921–1019. https://doi.org/10.1007/978-1-4615-0747-5_97

Muricy G, Lopes DA, Hajdu E, Carvalho MS, Moraes F, Klautau M, Menegola C, Pinheiro U (2011) Catalogue of Brazilian Porifera. Museu Nacional, Rio de Janeiro, Livros, 46, 300 pp.

Nimer E (1979) Climatologia do Brasil. Fundação Instituto Brasileiro de Geografia e Estatística, Rio de Janeiro, 422 pp.

Sollas WJ (1885) A Classification of the Sponges. Annals and Magazine of Natural History (5) 16(95): e395. https://doi.org/10.1080/00222938509459901

Trajano E, Bichuette ME (2006) Biologia Subterrânea. Redespeleo Brasil, São Paulo, 92 pp.

Volkmer-Ribeiro C, Turcq B (1996) SEM analysis of silicious spicules of a freshwater sponge indicate paleoenvironmental changes. Acta Microscopica 5(B): 186–187.

Volkmer-Ribeiro C, Tavares MC, Oliveira KF (2009) *Acanthotylotra alvarengai* (Porifera, Demospongie) new genus and species of sponge from Tocantins River, Pará State, Brazil. Iheringia. Série Zoologia 99(4): 1–4. https://doi.org/10.1590/S0073-47212009000400002

Volkmer-Ribeiro C, Bichuette ME, Machado VS (2010) *Racekiela cavernicola* (Porifera: Demospongiae) new species and the first record of a cave freshwater sponge from Brazil. Neotropical Biology and Conservation 5(1): 53–58. https://doi.org/10.4013/nbc.2010.51.08

WoRMS (2020) Demospongiae. http://www.marinespecies.org/aphia.php?p=taxdetails&id=164811 [accessed: 2020-12-20]